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Research Article

Data-Driven Periodic and Nonlinear Trends in Option Pricing: A Curve-Fitting Perspective

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ABSTRACT

This study presents a novel curve-fitting tuned methodology to model dynamic trends in data-driven option prices using various fitting models such as polynomial, exponential, Gaussian, and Fourier. It addresses the challenges of pricing options through mathematical modelling, analysing stock price uncertainties, and identifying the best trend fit. The proposed model captures trends and variability in the data, enabling the extraction of critical insights such as the rate of stock price changes over time and the ability to forecast future option prices. Using traded data from various sectors for stock prices between 13.11.2017 and 9.8.2019, statistical measures such as R-squared error, Sum of Squares Error (SSE), Degrees of Freedom Error (DFE), Adjusted R-squared, Root Mean Squared Error (RMSE), and parameter coefficients were evaluated for each model.

Keywords: Option Pricing, Non-Linear trend, Periodic trend, Curve fitting, Root Mean Square Error

INTRODUCTION

Derivatives have become indispensable in contemporary financial markets, with options being the most widely traded instruments. Options provide flexibility to investors, offering rights but not obligations to buy or sell an asset at a predetermined price before or on a specific expiration date. These instruments are classified into call options, allowing the purchase of assets, and put options, permitting the sale of assets, and further divided into European and American types based on their exercise conditions. The Black-Scholes model, introduced by Fischer Black and Myron Scholes in 1973, remains a cornerstone in option pricing. It offers a closed-form solution for European options, relying on assumptions such as constant volatility, no transaction costs, and lognormal asset price distribution. Despite its widespread adoption, the model's reliance on these simplifying assumptions often limits its applicability in dynamic and volatile market conditions.

The financial landscape has evolved to demand more sophisticated tools that better capture market complexities. Traditional models like Black-Scholes often struggle to incorporate real-world uncertainties, including abrupt price fluctuations and non-linear trends. To address these challenges, this study introduces an innovative curve-fitting methodology. By leveraging advanced mathematical and statistical tools, this approach seeks to enhance precision in modelling option price trends. The curve-fitting models aim to align closely with observed market data, providing a more robust framework for understanding and predicting price dynamics. The study focuses on historical data spanning two years, encompassing diverse sectors to ensure comprehensive insights. By comparing multiple models, including polynomial, exponential, Gaussian, and Fourier fits using its parameters, the research emphasizes identifying the most effective approach for accurately capturing data variability and trends.

LITERATURE REVIEW

The literature surrounding option pricing highlights extensive critiques and refinements of the Black-Scholes model. Gultekin, Rogalski, and Tinic (1982) emphasized the time-dependence of option values, validating the importance of temporal factors in pricing mechanisms. Gencay and Salih (2003) revealed significant pricing errors in Black-Scholes, particularly for deep out-of-money options under volatile conditions. They demonstrated that feedforward neural networks often outperform traditional models in such scenarios. Frino et al. (2019) validated the model's efficiency in the Australian stock market through cross-sectional data analysis, reinforcing its viability in certain contexts. Arun and Ravi (2021) explored factors influencing model performance, including underlying asset characteristics, contract duration, and moneyness, advocating for adaptive refinements. Meanwhile, Saurabha and Tiwari (2007) integrated skewness and kurtosis adjustments into the model, achieving closer alignment with market prices for S&P CNX Nifty index call options. These studies underscore the need for dynamic methodologies capable of adapting to the complexities of real-world markets, paving the way for advanced approaches like the one proposed in this study.

METHODOLOGY

This study adopts a comprehensive and rigorous methodology to analyze the dynamic trends in option prices using a curve-fitting approach. The research commenced with the acquisition of historical data on stock and option prices from various sectors, covering the period from 13.11.2017 to 9.8.2019. This data was subjected to meticulous preprocessing to eliminate inconsistencies and ensure accuracy. Key steps included the removal of outliers, normalization of data to a uniform scale, and interpolation for handling missing values.

The core of the methodology involved applying several curve-fitting models to uncover patterns within the data. Polynomial models of varying degrees (linear, quadratic, cubic, quatic) were tested alongside exponential, Gaussian, and Fourier models with its parameters. These models were carefully selected for their ability to represent diverse data behaviours, from simple linear trends to complex periodic patterns. Each model was fitted to the dataset using advanced statistical techniques, ensuring optimal alignment with observed trends.Performance evaluation formed a critical aspect of the methodology. Statistical metrics such as R-squared error, Sum of Squares Error (SSE), Degrees of Freedom Error (DFE), Adjusted R-squared, and Root Mean Squared Error (RMSE) were employed to assess model accuracy and reliability. R-squared quantified the proportion of variance explained by the model, while SSE measured discrepancies between predicted and actual values. DFE evaluated the efficiency of parameter usage, and Adjusted R-squared provided a balanced assessment of model complexity and performance. RMSE offered insights into the standard deviation of prediction errors.

An iterative process was employed to fine-tune model parameters, enhancing their predictive capabilities. Among the models tested, the Ploynomial (Quatic) fit emerged as the most effective, demonstrating superior alignment with observed data trends. This model's strength lies in its ability to capture periodic patterns and variability within the data, providing deeper insights into option price dynamics. The robustness of this methodology was further validated through cross-validation techniques, ensuring the generalizability of the findings. By integrating advanced statistical analysis and model optimization, the methodology provides a powerful framework for understanding and forecasting option price trends, offering significant implications for financial analysis and decision-making.

RESULTS AND DISCUSSION

Curve-fitting techniques serve as essential tools for aligning mathematical functions with observed market data, addressing complexities and revealing hidden patterns. They enhance prediction accuracy, minimize errors, and offer flexibility in choosing suitable models. The results of the curve-fitting analysis are summarized below:

Table 1. **Goodness of fit values**

Model	Equation	SSE	R-Squared	DFE	Adjusted R-Squared	RMSE	Parameters
Polynomial (Linear)	$f(x) = p_1x + p_2$	5.6342	0.3507	43041	0.3507	3.6180	p_1 = 0.0300, p_2 = -0.1980
Polynomial (Quadratic)	$f(x) = p_1x^2 + p_2x + p_3$	5.5833	0.3565	43040	0.3565	3.6017	p_1 = -0.0503, p_2 = 2.9207 p_3 = 2.0025
Polynomial (Cubic)	$f(x) = p_1x^3 + p_2x^2 + p_3x + p_4$	5.5765	0.3573	43039	0.3573	3.5996	p_1 =-0.0055, p_2 =0.0553 p_3 =2.7811, p_4 =1.9254
Polynomial (Quatic)	$f(x) = p_1x^4 + p_2x^3 + p_3x^2 + p_4x + p_5$	5.4913	0.3672	43038	0.3671	3.5720	p_1 =0.0028, p_2 =-0.0876, p_3= 0.6537, p_4 =2.2429 p_5 = 1.5484
Exponential	$f(x) = ae^{bx}$	7.6177	0.1221	43041	0.1221	4.2070	a =2.1472, b =0.1688
Fourier	$f(x) = a_0 + a_1\cos(xw) + b_1\sin(xw)$	5.5699	0.3581	43039	0.3581	3.5974	a_0 =14.884, a_1 = -13.0123 b_1 = 19.0145, w= 0.1417
Gaussian	$f(x) = a_1e^{\left(-\left(\left((x-b_1)/c_1\right)^2\right)\right)}$	5.8180	0.3295	43040	0.3295	3.6766	a_1 =61.205, b_1 =7.9040 c_1 =4.0823

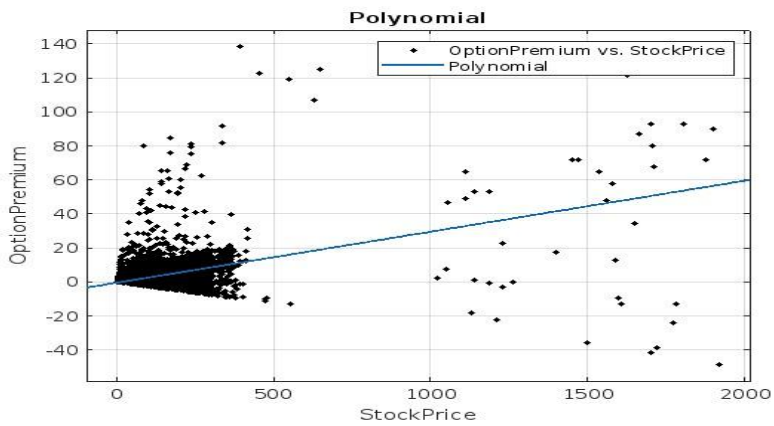

Figure 1. **Linear Fit model**

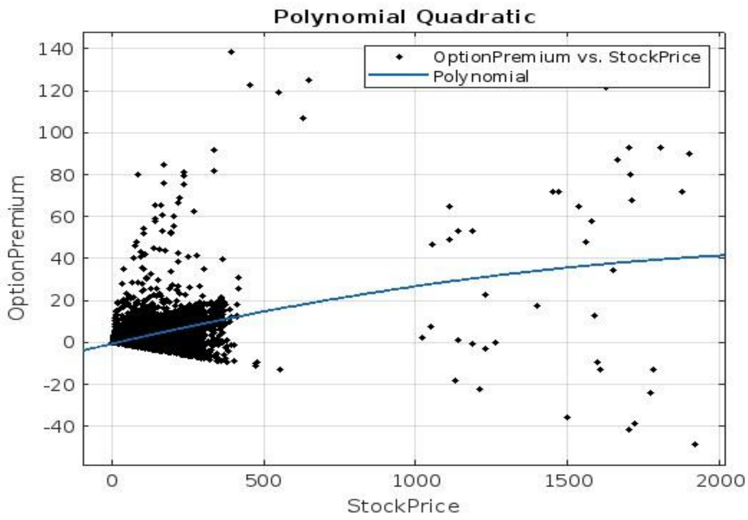

Figure 2. **Non-linear (Quadratic)fit model**

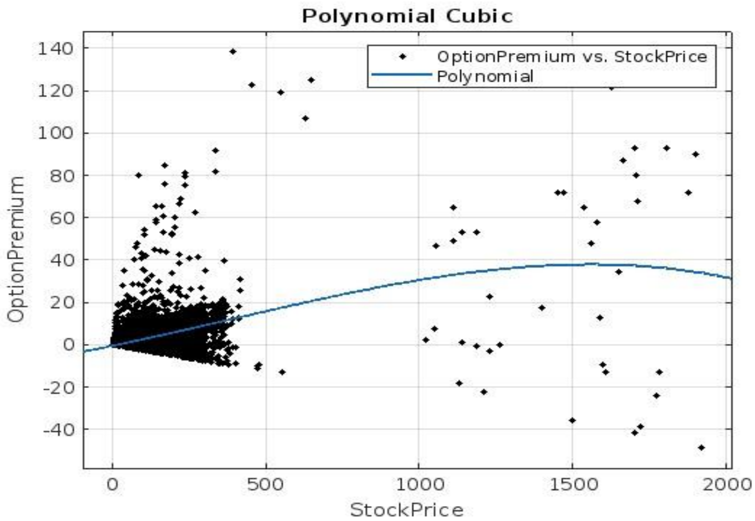

Figure 3. **Nonlinear(Cubic)Fit Model**

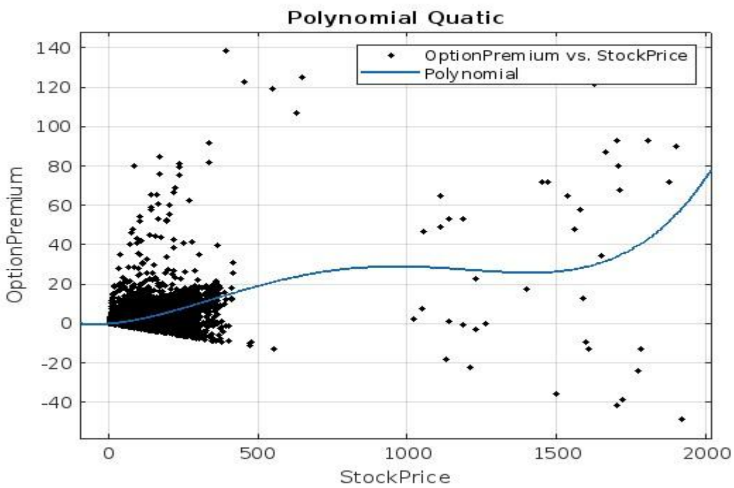

Figure 4. **Nonlinear(Quatic) Fit Model**

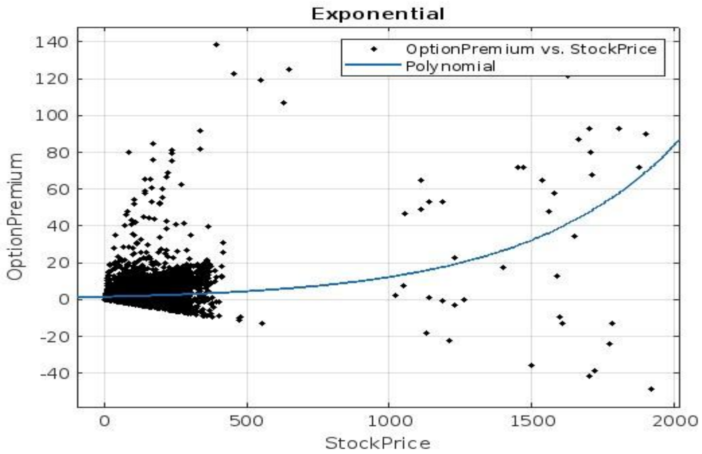

Figure 5. **Exponential Fit Model**

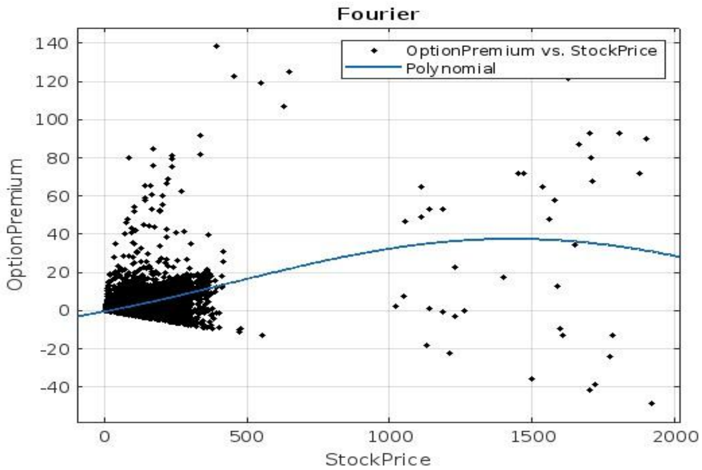

Figure 6. **Fourier Fit Model**

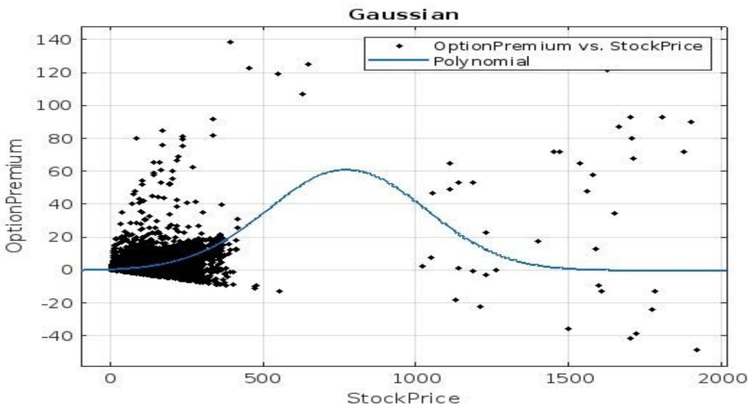

Figure 7. **Gaussian fit model**

The results highlight the polynomial(Quatic) fit model as the most effective among the models tested. It achieved high R-squared values, indicating a robust explanation of data variance, and minimal SSE, reflecting reduced prediction errors. The low RMSE further underscored its precision in capturing trends. The Polynomial(quatic) model's ability to represent periodic patterns and variability makes it particularly suitable for analysing option price dynamics. These findings demonstrate the model's utility in enhancing decision-making processes in financial markets by providing accurate and actionable insights.

Comparative analysis of other models revealed limitations in capturing complex trends, further emphasizing the Fourier model's superiority

CONCLUSION

This study introduces a curve-fitting tuned approach that significantly enhances the precision of option pricing models. By employing advanced statistical and mathematical techniques, the methodology effectively captures dynamic trends and uncertainties in market data. Among the tested models, the Polynomial(Quatic) fit demonstrated optimal performance, aligning closely with observed trends and offering reliable predictions. This approach provides a valuable tool for financial analysts and investors, particularly in volatile market conditions, by facilitating informed decision-making and risk management. The findings underscore the importance of adopting innovative methodologies to address the limitations of traditional models, paving the way for more accurate and dynamic financial analysis.

FUTURE DIRECTIONS

Future research can explore integrating additional factors, such as interest rates, macroeconomic indicators, and market volatility, to refine model accuracy further. Expanding the curve-fitting approach to include diverse asset classes and alternative option types can broaden its applicability. Developing automated techniques for model selection and parameter optimization can streamline the analytical process, enhancing efficiency and scalability. By addressing these areas, the proposed methodology can continue to evolve, offering even greater utility in the dynamic and complex landscape of financial modeling.

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